SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

JHRP-88/14

Final Report

DEVELOPMENT OF THE IDOH CLASSIFICATION SYSTEM FOR GEOTEXTILES

Dean A. Karcz
Robert D. Holtz

PURDUE UNIVERSITY

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TO:	H.L. Michael, Director Joint Highway Research Project	October 6, 1988
		Project: C-36-674
FROM:	R. D. Holtz, Research Engineer Joint Highway Research Project	File: 9-11-25

Transmitted herewith is the final report on the JHRP project "Classification of Geotextiles for Highway Purposes." The report is entitled "Development of the IDOH Classification System for Geotextiles." It was prepared by D. A. Karcz, Graduate Research Assistant, and Professor R. D. Holtz.

We have modified a geotextile classification system developed in France and made it more useful for IDOH engineers. Included in the new system are systematic design and selection procedures for geotextiles in routine filtration, drainage, and erosion control applications as well as for roadway subgrade stabilization.

We very much appreciate the interest and assistance of Mr. W. J. Sisiliano and his staff in the development of this classification system. We believe its use will improve the property selection and specifications for geotextiles on IDOH projects.

We look forward to your comments and those of the JHRP Board on our report.

Sincerely yours,

R. D. Holtz

R. D. Holtz
Research Engineer

RDH:cr

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FINAL REPORT

DEVELOPMENT OF THE IDOH CLASSIFICATION SYSTEM FOR GEOTEXTILES

by

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The financial support for this research was provided by the Indiana Department of Highways. Thanks are due to Bill Sisiliano and his staff at the Indiana Department of Highways for their comments and suggestions throughout the work on this project.

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Dean Andrew Karcz

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LIST OF SYMBOLS AND ABBREVIATIONS

AOS	apparent opening size
α	angle over which tire pressure distributes
CBR	California Bearing Ratio
c_u	undrained shear strength
D_{10}	grain size for 10% of the sample passing by weight
D_{15}	grain size for 15% of the sample passing by weight
D_{30}	grain size for 30% of the sample passing by weight
D_{60}	grain size for 60% of the sample passing by weight
D_{85}	grain size for 85% of the sample passing by weight
e	thickness of the geotextile
ϵ	elongation
h	height of aggregate without a geotextile
h_g	height of aggregate with a geotextile
HV	heavy vehicle traffic
i	hydraulic gradient
k_f	permeability of the fabric
k_n	permeability of the fabric normal to the plane
k_s	permeability of the soil
L	length of the tire

LV	light vehicle traffic
O_{15}	opening size at 85% passing
O_{50}	opening size at 50% passing
O_{95}	opening size at 5% passing
O_f	geotextile opening size = AOS
OS	out of specification traffic
p	stress applied at the base-subgrade interface
P	axle load
P_t	tire pressure
q_e	net elastic bearing capacity
q_n	net plastic bearing capacity
S	seconds
TW	total weight to which the structure will be subjected

HIGHLIGHT SUMMARY

When selecting a geotextile to be used in a highway design, the design engineer is faced with the task of choosing from hundreds of geotextiles. In order to assist the engineer in the specification of a geotextile, a system to classify and specify geotextiles has been developed for routine applications encountered by the Indiana Department of Highways. These applications include routine filtration/drainage, erosion control, and roadway stabilization applications. A system developed by the French Committee of Geotextiles and Geomembranes has been used as a model. Modifications were made to the system to make it applicable to Indiana Department of Highways projects. For roadway design the new system was combined with the U.S. Forest Service method for the design of temporary roads. This procedure may also be used to determine the amount of stabilization aggregate needed for permanent roads.

CHAPTER 1

INTRODUCTION

The use of geotextiles in transportation and geotechnical engineering is increasing rapidly. A major problem in choosing a geotextile for highway design is the number and diversity of products available.

The French Committee of Geotextiles and Geomembranes (References 7 and 8) has set up a system to classify geotextiles. The French system includes a classification scale which is divided into 12 classes based on five geotextile physical properties necessary for the design of a number of routine geotextile applications. These properties are tensile strength, maximum tensile elongation, tear resistance, permeability, and apparent opening size. This system allows one to develop specifications for geotextiles in such applications as parking lots, roadways, sports fields, drainage and filtration systems, and others.

1.1 Objective and Scope

The objective of this research has been to develop a system to classify and specify geotextiles for routine applications. These routine applications are some filtration and drainage applications, roadway stabilization, and some erosion protection systems. The French system was used as a model for this system. However, several modifications were necessary in order to create a useful system

for the Indiana Department of Highways. Some of the modifications included adding other geotextile properties to the classification system, reducing the number of classes in the scales of classification, and reducing the number of charts for the roadway design procedure.

It must be strongly emphasized that this system does not address the reinforcement function of geotextiles. While in some applications the geotextile may provide some reinforcement, this should not be assumed or expected. Reinforcement applications must be designed on an individual basis because of complex geotechnical and loading conditions.

1.2 Literature Review

Literature necessary not only for a general overview of geotextiles but for specific aspects of geotextiles addressed in this study is discussed below. These aspects include geotextile applications, design procedures, properties, and property testing.

There are a number of sources available that discuss the uses of geotextiles in geotechnical engineering. Christopher and Holtz (1985), Koerner (1986), and John (1987) provide thorough coverage of the various geotextile applications and design procedures. There are also a number of conferences on geotextiles (International Conference on the Use of Fabrics in Geotechnics, Paris, 1977; Second International Conference on Geotextiles, Las Vegas, 1982; Third International Conference on Geotextiles, Vienna, 1986), as well as other geotechnical conferences that address geotextiles.

Christopher and Holtz (1985) go into great detail on the uses of geotextiles in

filtration and drainage, roadway stabilization, and erosion control applications. Cedergren (1977) provides background material on the filtration criteria, which are used in natural soil filter design as well as geotextile applications. Rankilor (1981) discusses geotextiles in roadway and other applications, as well as providing a good overview of the geotextiles available. van Zanten (1986) and Christopher and Holtz (1985) discuss important geotextile properties and property tests.

This literature provided the background material such that proper decisions could be made with regard to the applications to address, which design procedures for these applications were most appropriate, and which properties to include in this research. For further discussions on these topics the reader is referred to the specific reference.

1.3 Report Arrangement

Chapter 2 of this thesis discusses the French classification system and how it was modified. The reasoning behind reducing the original number of classes in the French system and adding other geotextile physical properties to the scales of classification is discussed. A thorough explanation of how the system is to be used is covered as well. A brief description of the properties included in this system is also provided.

Chapter 3 discusses recommendations for the use of geotextiles in filtration/drainage and erosion control applications. Two different sets of recommendations are discussed: those recommended by the FHWA, and those recommended by the French Committee of Geotextiles and Geomembranes.

The reasoning behind recommending the use of the FHWA recommendations is discussed, and a computer program to be used as an aide in filtration/drainage and erosion control designs is provided.

Chapter 4 discusses the use of geotextiles in roads. The French recommendations for the use of geotextiles in roads have been combined with the U.S. Forest Service method for the design of temporary roads to provide a procedure to design the aggregate thickness as well as to provide the geotextile specifications for a given roadway application. This procedure is then applied to design the stabilization aggregate for permanent roads.

Examples are provided in Chapters 3 and 4 to illustrate the use of the system and the design methods covered in each respective chapter.

A summary, conclusions, and recommendations for further research are given in Chapter 5.

A copy of the computer program used for filtration/drainage and erosion control applications is provided in the Appendix. An example problem is solved and the input and output files for the problem are also given.

CHAPTER 2

DISCUSSION OF CLASSIFICATION SYSTEM

2.1 Separation of Properties

The French Committee of Geotextiles and Geomembranes developed recommendations for the use of geotextiles in various routine applications. These applications include temporary traffic lanes, low traffic lanes and improved subgrades, drainage and filtration systems, railroad tracks, storage and parking areas, parks, and sports and recreation areas. The purpose of these publications was to help in the selection of geotextiles for these different systems. It is important to note that these are routinely encountered applications. Systems that offer complexity due to such things as unusual geotechnical conditions or special applications, as in reinforcement, require individual evaluations.

It is believed that by separating into classes certain important geotextile properties, a useful systematic method of specifying geotextiles can be established. This procedure has been proposed by the French Committee of Geotextiles and Geomembranes.

The first step in establishing the classes of properties was to determine which properties are to be included. The properties chosen were those that are

important for the geotextile to survive construction and to function properly under post-construction conditions. The critical properties are:

a. Wide-Width Tensile Strength

b. Maximum Stress Elongation

c. Trapezoidal Tear Strength

d. Permittivity

e. Apparent Opening Size (AOS)

f. Grab Strength

g. Puncture Strength

h. Burst Strength

Permittivity is used rather than permeability because many fabrics are thick and compressible, and permittivity (permeability divided by thickness) takes the thickness into account.

Eight (8) classes were chosen for the IDOH system, versus the original 12 chosen by the French Committee. The number of classes was reduced in order to simplify the system. These classes cover the entire range of values for a given property, such that the classes are not to be too small and are a practical size.

Two approaches were followed to determine how the classes would be scaled for each property. First, a review of the properties of geotextiles currently on the market was made to find the range and main frequency of occurrence of a given property value. Second, Indiana Department of Highways specifications (1987) and AASHTO-AGC-ARTBA Task Force 25 (1986) recommendations were reviewed to determine what values are often specified for certain geotextile applications. These specifications and recommendations were used to help

determine where class boundaries could be set. The two approaches were then combined to establish how the range of values would be scaled. Table 2-1 shows the properties and their classes.

Table 2-1
Scales of Classification

PROPERTY	CLASS 1		2		3		4		5		6		7		8
WIDE-WIDTH TENSILE STRENGTH (lb/in.)		35		70		100		140		[illegible]		285		500	
MAXIMUM STRESS ELONGATION (%)		8		15		25		35		50		75		100	
TRAPEZOIDAL TEAR STRENGTH (lb)		25		50		100		200		400		700		1000	
PERMITTIVITY (s^{-1})		$2x10^{-2}$		$5x10^{-2}$		0.1		0.5		1.0		5.0		10.0	
AOS (μm)		600		400		250		200		150		100		50	
GRAB STRENGTH (lb)		80		130		180		230		300		400		500	
PUNCTURE STRENGTH (lb)		25		50		75		100		150		200		300	
BURST STRENGTH (psi)		75		150		225		300		400		500		700	

By using this method one then knows that, for example, for a given application a geotextile may be specified with Class 4 grab strength, Class 3 burst strength, Class 6 puncture strength, etc.

The classification system may be used in two different ways. For drainage applications, the geotextile properties must be determined using procedures outlined in Chapter 3. Once these properties are determined, the specific classes for each property can be established from Table 2-1. The second method in which the system may be used is found in Chapter 4, the chapter on geotextiles used in roads. In this method reference is made to a specification chart based on conditions necessary for design of the roadway system. These necessary conditions are traffic, subgrade strength, fill material type, and rut depth. This specification chart gives the property classes for a geotextile to be used to help write the geotextile specifications.

It is the intention of this research that the system developed be used to assist in the writing of specifications for geotextiles. The scales of classification (Table 2-1) offer a format for giving specifications. As an example of how to use the system, assume that a geotextile to be used in a drainage application has had the following properties determined to be necessary:

Property	*Value*
Grab Strength	$>$ 160 lb
Elongation	$>$ 30 %
Puncture Strength	$>$ 80 lb
Burst Strength	$>$ 290 psi
Maximum AOS	0.60 mm
Minimum AOS	0.20 mm
Permeability	$>$ 0.03 cm/sec

By referring to the scales of classification, and taking the next highest class when necessary, the following classes are established:

Property	*Class*
Grab Strength	3
Elongation	4
Puncture Strength	4
Burst Strength	4
AOS	$1 \leq$ Class ≤ 4

With the exception of the AOS, all of the properties must be of equal or higher class for a given geotextile to be used. The permeability criteria must be met by reviewing the permittivity and thickness of each geotextile that is being considered. It should be noted that all properties are not necessarily specified for a given application (such as trapezoidal tear and wide-width tensile strength in this case). More thorough examples are given in later chapters, covering the

design procedures and specifications assessment in more detail.

The system has been set up such that if it is to be applied to special applications, properties other than those chosen in Table 2-1 can be considered (i.e. creep, temperature resistance, dynamic tearing). Flexibility of the system will make it an even more useful tool for designs incorporating geotextiles.

2.2 Discussion of Geotextile Properties

When designing with geotextiles it is necessary to understand the properties required to ensure an adequate design. Geotextiles can be separated into woven fabrics, nonwoven fabrics, knitted fabrics, webs, mats, grids, and composites. Determining the material and construction of the geotextile to be used in a given application depends on the properties required. The properties of a geotextile are often dependent on the properties of the fibers and the fabric construction, referred to as the structure of the geotextile (van Zanten, 1986). Christopher and Holtz (1985) provide a description of the geotextile properties listed in the following sections, and available ASTM and other tests for these properties.

2.2.1 Mechanical Properties

Loading on a geotextile may be in the plane or perpendicular to the plane of the geotextile, requiring the fabric to have sufficient strength in both directions. In tensile tests the geotextile is subjected to loads and/or displacements in the plane of the geotextile.

2.2.1.1 Grab Tensile Strength. This test value is more appropriately used in comparisons between similar geotextiles than as a design parameter. In situations where field evaluation or laboratory simulation show a geotextile of a

certain grab strength to perform successfully, that grab strength may be used to specify the geotextile to be used in the given application. Such is the case for filtration and drainage applications. The grab tensile strength test has been standardized by ASTM as test D 4632-86 (Reference 1).

2.2.1.2 Wide-Width Strip Strength. The wide-width strip tensile test provides a more realistic value of the strength of the fabric due to the higher aspect ratio (width/length) than the grab tensile test. The strain rate is also slower than the grab tensile strength, reducing the rapid loading effects. The maximum tensile stress is accompanied by the strain at failure (also known as maximum elongation). The wide width strip strength test has been standardized by ASTM as test D 4595-86 (Reference 1).

2.2.1.3 Trapezoidal Tear Strength. Geotextiles can be cut or punctured during field installation, leading to stress concentrations. When these stress concentrations occur, the geotextile may tear. The tear strength is measured by the trapezoidal tear strength method. Reference is made to ASTM test D 4533-85 (Reference 1) for the standardized trapezoidal tear strength test method.

2.2.2 Rupture Resistance

The geotextile is subjected to concentrated normal loads during construction and during the life of the system. These loads could be due to stumps, boulders and rocks, and cut brush. The geotextile could either be subject to burst from the blunt objects, or puncture from sharp or pointed objects. For these reasons the burst and puncture strength are recommended for survivability of the

geotextile. There are three test methods for burst strength: Mullen burst test, ball burst test, and the CBR plunger test. The Mullen burst test is recommended by the *FHWA Geotextile Engineering Manual* (Christopher and Holtz, 1985). Koerner (1985) states that the puncture test is a popular test used primarily as an index test, but has direct applicability to the field when properly modeled. In the past a puncturing ball was used in the test, but this has been replaced by a 5/16 in. blunt-end metal rod.

2.2.3 Hydraulic Properties

For the transport of fluids and the prevention of unwanted particle movement, hydraulic properties must be met. Permittivity (permeability divided by the geotextile thickness) provides for the transport of water through the geotextile. Permittivity will be discussed further in Chapter 3. The AOS of a geotextile is an important hydraulic property. The AOS is the U.S. Standard Sieve number of the geotextile opening such that 95% of these openings are smaller than this size. A series of glass beads of known size and number are sieved until 5% or less by weight pass through the fabric. The AOS is the "retained on" sieve number of this fraction. The AOS is also known as the O_{95} when given in millimeters. Reference is made to the *FHWA Geotextile Engineering Manual* (Christopher and Holtz, 1985) for the test procedure to determine the AOS.

CHAPTER 3

DESIGN OF GEOTEXTILES FOR COMMON FILTRATION, DRAINAGE AND EROSION CONTROL APPLICATIONS

Filtration/drainage applications include under-drains, interceptor drains, and pavement structure drains. Erosion control applications entail cut and fill slope protection, bank and shore erosion control systems, and sediment erosion control systems (silt fences and silt curtains).

3.1 FHWA Design Recommendations

The design criteria covered by this procedure are soil retention, permeability, clogging, and survivability. It is important that all of these criteria be met, as not taking one of the requirements into account could result in failure. Many of the general fundamental filtration requirements for granular filters are applied to geotextile design to meet the retention and permeability criteria.

It is necessary to classify each project as to its critical nature and the severity of the hydraulic and soil conditions at the site. Carroll (1983) developed guidelines for evaluating a geotextile application, as shown below.

Table 3-1
Guidelines for Evaluating the Critical Nature or Severity of Drainage and Erosion Control Applications
(Christopher and Holtz, 1985, adapted from Carroll, 1983)

	Item	Critical	Noncritical
1.	Risk of loss of life and/or significant structural damage due to drain failure:	High	None
2.	Evidence of drain clogging before potential catastrophic failure:	None	Yes
3.	Repair costs vs. installation costs of drain:	>>	= or <

Severity of the Conditions Summary

	Item	Severe	Nonsevere
1.	Soil to be drained	Gap-graded pipable	Well-graded uniform
2.	Hydraulic gradient	High	Low
3.	Flow conditions	Dynamic cyclic or pulsating	Steady state

3.1.1 Retention Criteria

Two types of soils are distinguished for the retention criteria -- those with less than 50% passing the U.S. No. 200 sieve (sand), and those with more than 50% passing (silts and clays). The type of flow to be encountered, steady state or dynamic, must also be taken into account. For granular material in steady state conditions the grain size distribution of the soil is taken into account in determining the apparent opening size (AOS) of the geotextile. The AOS value and test procedure has been discussed in Chapter 2. Table 3-2 gives the retention criteria depending on the soil and type of flow.

Table 3-2
Soil Retention Criteria
(Revised by Holtz, from Christopher and Holtz, 1985)

Soils	Steady State Flow	Dynamic, Pulsating, and Cyclic Flow
< 50% Passing U.S. No. 200 sieve (sands)	AOS or $O_{95} = B\ D_{85}$ For $C_u < 2$ or > 8, $B = 1$ $2 < C_u < 4$, $B = 0.5\ C_u$ $4 < C_u < 8$, $B = 8/C_u$	$O_{95} < D_{15}$ (if soil can move beneath geotextile) or $O_{50} < 0.5\ D_{85}$
> 50% Passing U.S. No. 200 sieve (fines)	Woven: $O_{95} < D_{85}$ Nonwoven: $O_{95} < 1.8 D_{85}$ AOS or $O_{95} < 0.3$ mm	$O_{50} < 0.5\ D_{85}$

Notes: 1. When the protected soil contains particles from 1 inch size to those passing the U.S. No. 200 sieve, use only the gradation of soil passing the U.S. No. 4 sieve in selecting the geotextile.

2. Select geotextile on the basis of largest opening value required.

3.1.2 Permeability Criteria

Depending on the critical nature and severity of the application, two permeability criteria are established. For noncritical, less severe applications, the permeability of the fabric (k_f) is required to be at least greater than the permeability of the soil (k_s) the fabric is to retain.

$$k_f \geq k_s \tag{3.1}$$

For critical-severe applications the fabric permeability must be at least ten times greater than the permeability of the soil.

$$k_f \geq 10k_s \tag{3.2}$$

In some erosion control systems, quite often large fabric areas are covered by stone or concrete blocks. In these cases the permeability of the fabric should be based on the area of the fabric open for flow.

To determine the permeability of a geotextile, the ASTM Committee on Geotextiles has developed a test method, the standard of which is ASTM test D 4491-85 (Reference 1). Methods for determining the permeability of the soil can be found in Holtz and Kovacs (1981), Das (1985), and most other basic soil mechanics texts.

3.1.3 Clogging Criteria

Clogging occurs as a result of fine particles getting caught in the fabric pores, thereby blocking them. The clogging criteria is such that the particles that do enter the fabric pass through. For less critical-less severe applications the fabric with the lowest possible AOS (maximum opening size, mm) determined from the retention criteria and permeability criteria should be used to prevent clogging.

As an additional qualifier, by specifying the fabric pores to be three times larger than the particle which is to pass through the fabric, the particle is ensured of passing. The D_{15} is the particle size which is designed for such that particles of that size or smaller will pass through the pores. This criteria is given by the equation:

$$O_{95} \geq 3D_{15} \tag{3.3}$$

As another qualifier to ensure that the smaller pores in the fabric will allow the small particles to pass, it is recommended that the O_{15} be three times greater than the D_{15}, as well:

$$O_{15} \geq 3D_{15} \tag{3.4}$$

If the O_{95} calculated from the clogging criteria ($\geq 3D_{15}$) is greater than the AOS calculated from the retention criteria, the soil is uniform. In the case of uniform silts and some uniform sands some sort of filtration study must be performed.

For critical-severe applications it is necessary that the soil-geotextile interaction be considered in order to determine the performance of a geotextile for retention and clogging criteria. Such methods of modeling include slurry filtration tests, the gradient ratio test, permeameter filtration studies, and others.

The gradient ratio test is recommended by the FHWA as the filtration test to be run in these soils (see the *FHWA Geotextile Engineering Manual* (Christopher and Holtz, 1985) for a description of the test). The gradient ratio should be less than 3 for a given geotextile-soil system.

3.1.4 Survivability Criteria

The survivability criteria are based on AASHTO-AGC-ARTBA Task Force 25 (1986) recommendations. For either application, filtration/drainage or erosion control, two classes are specified.

* Filtration and Drainage

Class A - Installation stresses more severe than Class B

- Sharp, angular aggregate is used
- Heavy degree of compaction
- Depth of trench is greater than 10 feet

Class B - Surfaces are smooth graded having no sharp angular projections

- Rounded aggregate is used
- Light degree of compaction
- Depth of trench is less than 10 feet

* Erosion Control

Class A - Installation stresses more severe than for Class B

- Stone placement height is less than 3 feet
- Stone weights are less than 250 pounds

Class B - Fabric is protected by a sand cushion, or zero drop height for rip rap placement

The Task Force 25 recommended minimum property values for these applications are given in Table 3-3 below:

Table 3-3
Task Force 25 Recommended Minimum Survivability Property Values (1986)

	Drainage		Erosion Control	
Test Method	Class A	Class B	Class A	Class B
Grab Strength	180 lb	80 lb	200 lb	90 lb
Elongation	NS	NS	15 %	15 %
Puncture Strength	80 lb	25 lb	80 lb	40 lb
Burst Strength	290 psi	130 psi	320 psi	145 psi
Trapezoidal Tear	50 lb	25 lb	50 lb	30 lb

NS - not specified

Erosion control is discussed in more detail in a later section of this chapter.

3.2 French Recommendations

The French Committee of Geotextiles and Geomembranes (Reference 7) considers that a geotextile used in applications where water flow is to be encountered may either (a) perform a filter function, or (b) perform a filter and drain function. In case (a) the flow takes place perpendicular to the plane of the geotextile. To perform the filter function the geotextile must retain the soil particles and have sufficient permeability. In case (b) the geotextile transports water within its plane of thickness, thereby performing the drain function. However, the water must first be allowed to flow into the geotextile without

clogging, meaning the filter function must still be fulfilled. Excessive clogging cannot be tolerated, as this would reduce the transmissivity of the geotextile.

3.2.1 Filter Function

As mentioned previously, to perform the proper filter function the geotextile must have adequate retention and permeability criteria.

3.2.1.1 Retention Criteria. The retention criteria is specified such that the geotextile opening size O_f, is less than some coefficient times the D_{85} of the soil:

$$O_f < C * D_{85} \tag{3.5}$$

where C is a coefficient considering soil grain size distribution, soil compactness, type of discharge, and geotextile function, or $C = C_1 * C_2 * C_3 * C_4$. The C_i's are given as follows:

C_1 - influence of grain size distribution

Well graded -- $C_1 = 1.0$

Uniform -- $C_1 = 0.8$

C_2 - soil compactness

Loose and unconfined -- $C_2 = 0.8$

Dense and confined -- $C_2 = 1.25$

C_3 - hydraulic discharge

Hydraulic gradient $i < 5$ -- $C_3 = 1.0$

$5 < i < 20$ -- $C_3 = 0.8$

$20 < i < 40$ -- $C_3 = 0.6$

C_4 - geotextile function

Function of filter alone -- $C_4 = 1.0$

Function of homogeneous

drain filter -- $C_4 = 0.3$

3.2.1.2 Permeability Criteria. To satisfy the permeability criteria a minimum permittivity must be met by the geotextile. Permittivity is the permeability of the geotextile divided by the thickness. As thick geotextiles compress due to construction and earth pressure, the permittivity changes.

To account for the reduction in geotextile permittivity due to compression, as well as taking into account the importance and critical nature of the structure, three levels of permittivity are specified:

1. High security structures (earth dams)

$$\frac{k_n}{e} \geq 10^5 k_s \tag{3.6}$$

where

$\frac{k_n}{e}$ = permittivity

k_s = permeability of soil to be drained

2. Drainage trenches

$$\frac{k_n}{e} \geq 10^4 k_s \tag{3.7}$$

3. For clean sand (all applications)

$$\frac{k_n}{e} \geq 10^3 k_s \tag{3.8}$$

3.2.2 Drainage

The French Committee procedure (Reference 7) states that when a geotextile is used as a drain, it must meet three requirements:

1. The geotextile must not clog. To ensure clogging does not take place follow the filter rules.

2. Determine the effective stress on the geotextile, which can then be used to find the useful transmissivity. The effective stress on the fabric will depend on whether the geotextile is placed vertically, horizontally, or inclined.

3. The draining system, consisting of the drain and collector pipes, is designed by taking into account the quantity and direction (i.e. horizontal or vertical) of flow.

3.3 Selection of Filtration/Drainage Recommendations

There are a number of aspects of the French recommendations that make their use difficult. First, the C coefficient used in defining the filter criterion is based on certain soil characteristics that may not be known in all cases. The hydraulic gradient is one such characteristic; and also the distinction between loose and dense soil is rather ambiguous. The question of exactly how much the effective stress reduces the transmissivity of the geotextile is not addressed by the French Committee.

The FHWA recommendations (Christopher and Holtz, 1985) may be applied

by having knowledge of necessary conditions needed to provide an adequate design: soil conditions, flow conditions, and fabric pore dimensions. The soil and flow conditions should be known, regardless of whether a geotextile is used or not, in order to design with confidence. The fabric dimensions (AOS, permeability, etc.) can be determined from testing referred to in Chapter 2.

3.3.1 Computer Program

A computer program has been developed which follows the FHWA procedure. It may be applied to filtration and drainage applications. This program is to be used as a design tool to assist in the specification of geotextiles. It is not to be used as a substitute to the modeling of soil-geotextile interaction where required. The computer program provides geotextile property specifications. The next step is to determine the class for each of these properties from the scales of classifications (Table 2-1). A further explanation and a copy of the program can be found in the Appendix.

3.4 Erosion Control

The use of geotextiles in erosion control applications includes erosion control along waterways (both bank and shore), scour protection systems, cut and fill slope protections, and rainfall erosion control systems. Prior to the advent of geotextiles (and still common today) graded aggregate filters were used between the natural soil and protective covering. The need for the filters was due to the drainage openings exposing the underlying soil to erosion (John, 1987). These aggregate filters were at times multi-layered due to the difference in particle size between the natural soil and cover material. The geotextile replaces many of

the layers in the filter, thus simplifying construction.

The main difference between design for erosion control and design for filtration and drainage is the survivability requirements. In most situations the survivability requirements of geotextiles used in erosion control applications will be higher than those required in filtration and drainage. This increase is due to the use of rip-rap on top of the geotextile. Types of material used as protective covering include:

1. Rock rip-rap
2. Concrete blocks
3. Concrete mattresses
4. Gabion mattresses

Another difference between the design for erosion control and the design for filtration and drainage is that along waterways reversing flow is common. The chance of a graded soil filter forming is then quite small; hence the need for a geotextile. The graded soil filter is formed by fine particles initially moving through the geotextile while large particles adjacent to the fabric bridge the openings. Behind this soil bridge a soil filter is formed. This soil filter retains any particles in the water that flows through the filter, while the geotextile ensures that the soil filter remains in place. Lawson (1982) states that the soil filter acts as a reverse granular filter constructed of in-situ soil particles. Flow in opposite directions therefore prevents this filter from forming.

The amount of strength required by the geotextile for erosion control techniques depends on the type and size of rip-rap, and the method of placement.

Quite large (5000 lb) stones have been used in erosion control applications. For these large rip-rap applications the likelihood of the stones puncturing or tearing the geotextile is quite high. For this reason in some instances a sand or gravel protective layer is first placed upon the geotextile. This cushioning layer reduces the tear potential caused by protrusions on the rocks. Sand layers provide other functions, as well. In instances where precast concrete blocks are carefully placed into position, the sand layer is not so much acting as a cushion, but as a pore water dissipator. This can be an important function, as a major portion of the fabric may be covered by the blocks. Coarse sand used as a cushioning layer tends to promote a more even flow pattern in the underlying soil as shown in Figure 3-1. The cushion may be omitted in situations where the water forces are relatively small and/or where a thick, durable geotextile is used beneath a placed concrete mattress.

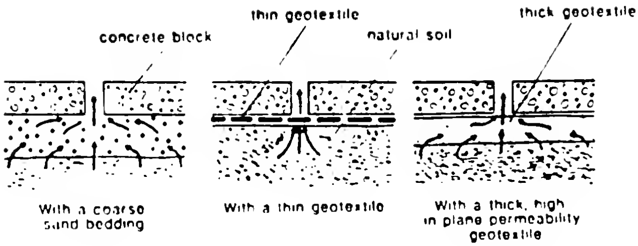

Figure 3-1

Flow Pattern in Underlying Soil (John, 1987)

Important in the placement of the rip-rap is the height of drop. Unprotected geotextiles can be damaged from heavy angular stones being dropped. Other factors that influence the amount of damage that can be incurred by the geotextile are:

1. Shape of stones
2. Tension in geotextile
3. Stiffness of subsoil
4. Properties of the geotextile
5. The medium through which stones are dropped.

By using a cushioning layer between the geotextile and rip-rap, one may

utilize less stringent protected strength criteria. Obviously, for applications where the rip-rap is placed directly on the geotextile, higher strengths will be required than for a protected geotextile.

The seepage of the cushioning must be adequate so as to allow free drainage of the slope. If not, hydraulic uplift pressure can cause a problem. Uplift can be prevented by ensuring the permeability of the geotextile is adequate and that the cover material force downward exceeds the uplift pressure force. Uplift pressures can be caused by a number of factors (van Zanten, 1986):

- the permeability and differences in permeability of the soil in and under the structure
- the geometry of the system
- the water storage capacity of the subsoil
- the location of any impermeable layers in the subsoil

Due to the large number of factors and their variability, there is no straightforward method for determining the uplift pressure. The uplift pressure can be estimated by using electric analogues or equations such as those found in van Zanten(1986) and John(1987).

3.4.1 Computer Program

The computer program developed for filtration/drainage has also been applied to erosion control. The same restrictions apply with regard to the modeling of soil-geotextile interaction where required.

CHAPTER 4

GEOTEXTILES IN ROADS

4.1 Temporary Roads

Temporary roads are typically low traffic volume structures which perform such functions as temporary access roads and haul roads. Most often temporary roads are unsurfaced, but they may be paved with a thin wearing course or stabilized in some manner.

Rankilor (1981) states that if a temporary road is to be constructed on a poor subgrade a geotextile may perform several functions (separation, reinforcement, filtration, and drainage) which combine to form a substantial and observable effect on the structure. Separation is the most dominant function of geotextiles in roadway applications. However, in other situations the reinforcing function may also influence performance. Therefore, there are two design approaches for unpaved roads: (1) considering separation only, and (2) including both separation and reinforcement.

The design which considers separation only is normally applied to low embankments. To provide separation, the fabric must be designed to retain the soil particles. The design procedures outlined in Chapter 3 are applicable to establish the retention criteria, as well as the required permeability in the case of

wet soil conditions. The strength of the geotextile must also be adequate to survive the high stresses induced during construction.

The design of geotextiles considering both separation and reinforcement requires a more thorough analysis of the geotextile properties and geotechnical conditions. Christopher and Holtz (1985) review a number of design approaches for temporary roadways. Two approaches which are widely used were developed by Steward, Williamson, and Mohney (1977), and Giroud and Noiray (1981).

4.1.1 Steward, Williamson, and Mohney (1977)

The design procedure developed by Steward, Williamson, and Mohney (1977) is used by the U.S. Forest Service. The design provides a depth of aggregate for a given subgrade strength, wheel load, and tire pressure. The procedure does not require that any strength or modulus values for the geotextile be known. It is assumed that the geotextile will be of sufficient strength to survive construction.

Procedure (as taken from Christopher and Holtz, 1985):

1. Determine the soil strength in the field using the cone penetrometer, vane shear, field CBR, or other suitable methods. John (1987) gives a conversion of CBR values into undrained cohesion as follows:

CBR	c_u(kN/m^{2})	c_u(psi)
1	28	4.1
2	55	8.0
3	90	13.1
4	120	17.4
5	150	21.8

2. Determine the design strength as the 75th percentile strength for each set

of readings at each depth. The 75th percentile is the strength at which not more than 75% of the soil strength readings are higher than this value.

3. Determine the maximum single wheel load, maximum dual wheel load, and the maximum dual tandem wheel load anticipated for the road during the design period.

4. Determine the required aggregate thickness from the load-stress depth curves (Figures 4-1, 4-2, and 4-3) for each maximum loading. Enter the curve with stresses equal to 2.8, 3.3, 5, and 6.0 times the design strength for each depth at each location.

5. Select the design thicknesses for different segments, as differing subgrades warrant. The design depth should be to the next highest 1-in. thickness.

To go into the charts a stress level value of C is chosen depending on the traffic and the amount of rutting which is acceptable. The stress level is chosen from the table below.

Stress	*Rutting*	*Traffic*	*Fabric?*
2.8C	< 2 in.	>1000 18K axle equivalencies	NO
3.3C	> 4 in.	<100 18K axle equivalencies	NO
5.0C	< 2 in.	>1000 18K axle equivalencies	YES
6.0C	> 4 in.	<100 18K axle equivalencies	YES

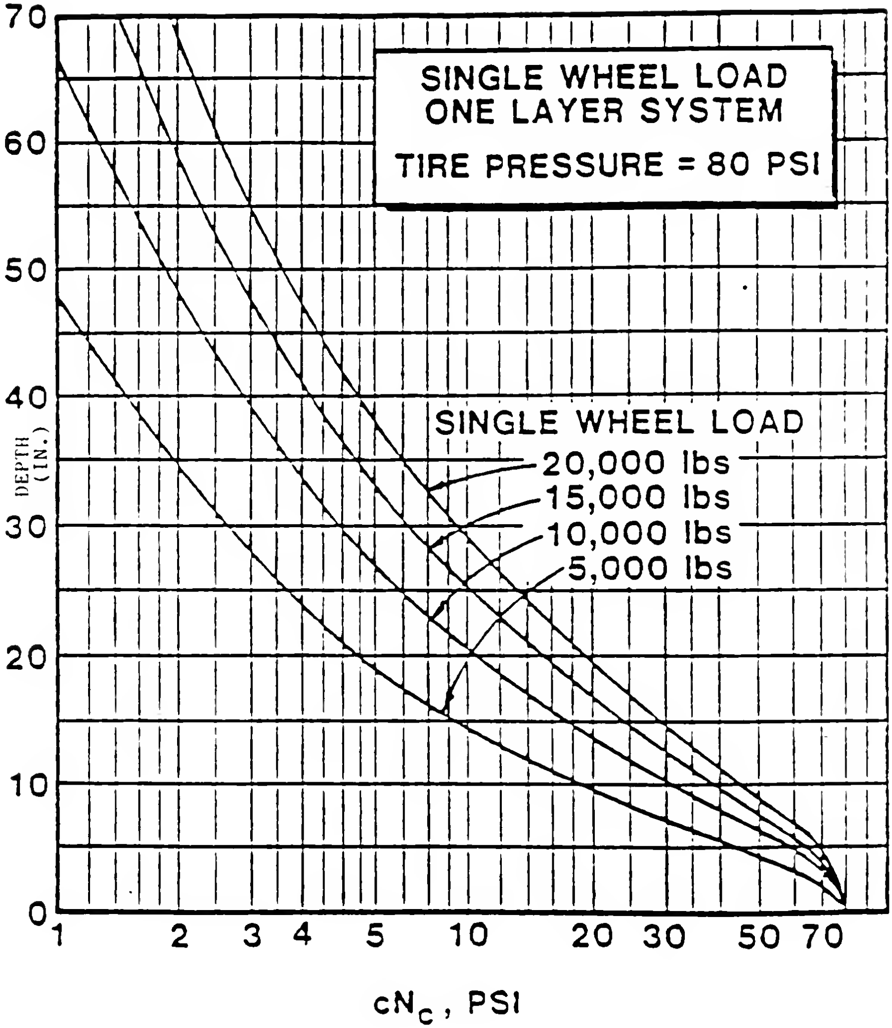

Figure 4-1
U. S. Forest Service Thickness Design Curve for Single Wheel Load
(Steward, et al., 1977)

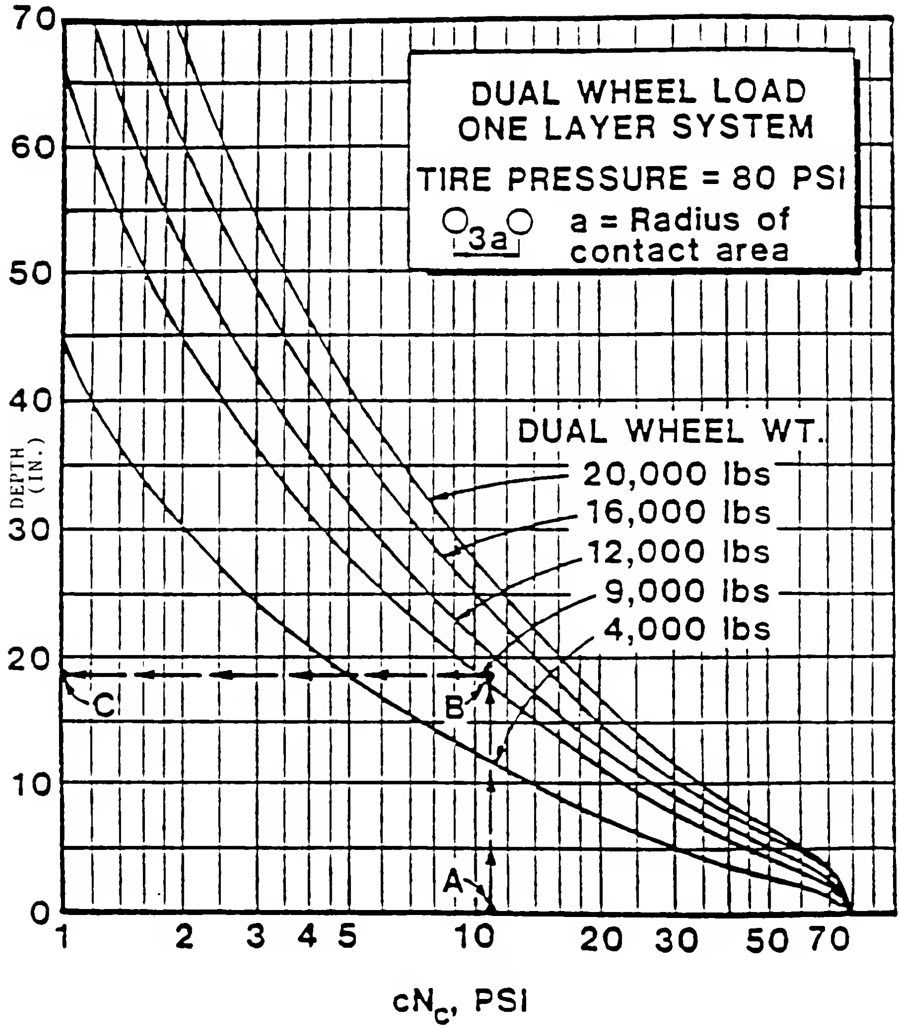

Figure 4-2
U. S. Forest Service Thickness Design Curve for Dual Wheel Load
(Steward, et al., 1977)

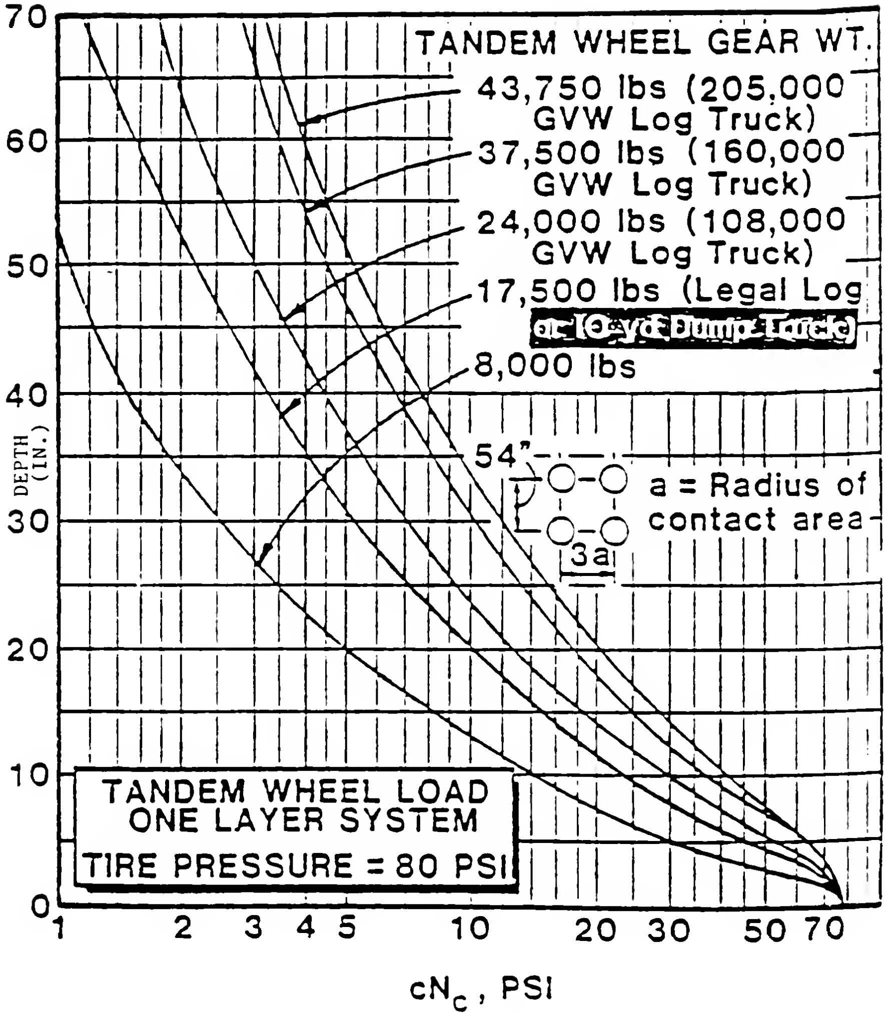

Figure 4-3
U. S. Forest Service Thickness Design Curve for Tandem Wheel Load
(Steward, et al., 1977)

4.1.2 Giroud and Noiray (1981)

The following assumptions are made in this design method (Christopher and Holtz, 1985).

a. The aggregate used for the fill material are of such quality that no shear failure occurs in it.

b. Friction between geotextile and fill is sufficient to prevent the fill from sliding at the soil-geotextile interface.

c. Wheel loads are distributed uniformly over an area which increases with fill depth according to the 2:1 stress distribution procedure.

d. Traffic does not exceed 10.000 vehicle passages and all vehicles travel in the same wheel paths.

Procedure:

1. Referring to Figure 4-4, the equivalent contact area, width B X length L. of a wheel is determined according to the following:

   i. Normal highway vehicles

$$B = \sqrt{\frac{P}{P_t}} \qquad (4.1)$$

$$L = 0.707B$$

where P_t = tire pressure

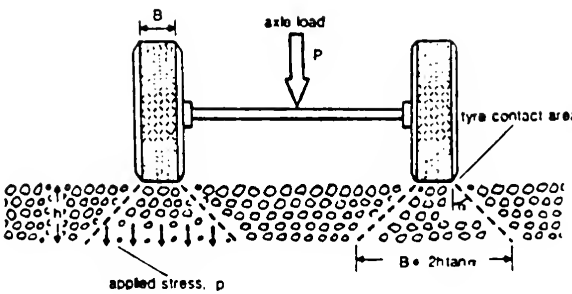

Figure 4-4
Notation for Giroud and Noiray Analysis
(John, 1977)

ii. Off-road vehicles

$$B = \sqrt{1.414\frac{P}{P_t}} \tag{4.2}$$

$$L = 0.5B$$

2. The stress applied at the base-subgrade interface by the axle is:

$$p = \frac{P}{2}(B + 2h\tan\alpha)(L + 2h\tan\alpha) \tag{4.3}$$

A good value of tan α has been found to be 0.6, so that:

$$p = \frac{P}{2}(B + 1.2h)(L + 1.2h) \tag{4.4}$$

3. The net elastic bearing capacity (q_e) and the net ultimate or plastic bearing capacity (q_p) are defined as:

$$q_e = \pi c_u \tag{4.5}$$

$$q_p = (\pi+2)c_u \tag{4.6}$$

where c_u is the undrained shear strength of the soil.

4. Without the fabric, the soil pressures are assumed to not exceed the elastic

limit of the soil ($q_e = \pi c_u$). Substituting Eq. 4.5 into Eq. 4.4:

$$\pi c_u = \frac{P}{2}(B + 1.2h)(L + 1.2h) \tag{4.7}$$

5. With a geotextile the soil pressures can be increased to the ultimate bearing capacity of the soil [$q_p = (\pi+2)c_u$]. Eq. 4.4 then becomes:

$$(\pi + 2)c_u = \frac{P}{2}(B + 1.2h_g)(L + 1.2h_g) \tag{4.8}$$

6. The saving in aggregate is then found from:

$$\Delta h = h - h_g \tag{4.9}$$

   where h is from Eq. 4.7

Giroud and Noiray (1981) suggest that the following three factors contribute to the extra stability arising from the presence of a geotextile in an unpaved road base:

i. Enhanced confinement of the subgrade soil

ii. Greater spread of the loading

iii. An uplift force due to the geotextile tension

When continuous sheets of woven or nonwoven geotextiles are used factor ii disappears, and for most cases the uplift force due to the geotextile tension can be ignored (John, 1987). The confinement of the subgrade soil is therefore the cause of the enhanced stability. For this reason the ultimate bearing capacity is used in step 5 above.

These equations are calculated on the assumption of very light traffic (less than 20 passes). However, modifications to the basic equation have been made

to take into account heavy traffic and can be found in Giroud and Noiray (1981), Christopher and Holtz (1985), and John (1987).

4.1.3 Discussion of French System as Applied to Roadway Design

One set of French Committee recommendations (Reference 8) was for the use of geotextiles in temporary traffic lanes, low traffic lanes, and improved subgrades. Included in this set were some 88 separate grids or charts for different cases of traffic, service life level, subgrade quality, and fill material.

To adapt the French system to one that would be more useful to the Indiana Department of Highways, it was believed that fewer charts had to be prepared than the original 88 given. In order to determine which case to refer to certain parameters were needed: the traffic tolerated by the lane, desired service life level, the subgrade quality, and fill material characteristics. Certain cases established by the French were not included in this system due to excessive rut depth, multiple layers of geotextiles, or subgrades of sufficient strength that a geotextile probably is not necessary.

The French had allowed a rut depth range of from 2 to 15cm (1 to 6 in.). The upper limit of 6 in. seemed much greater than acceptable, so a 3 in. rut depth was established as the upper limit. In the French system three different subgrade qualities were distinguished:

a. CBR > 5

b. $5 >$ CBR > 2

c. $2 <$ CBR

A CBR of 3 is suggested as the maximum subgrade strength for which a geotextile is necessary (Christopher and Holtz, 1985). Above a CBR of 3 subgrade intrusion is not a problem. The grids in the range of 5 > CBR > 2 could not be separated to determine those with CBR < 3. Therefore, only those cases in which subgrades with CBR < 2 are included in the IDOH system.

Using the above restrictions, eight cases were deemed useful for geotextile applications in temporary roads. Before going into these specific cases, it is necessary to explain how the classification system works.

4.1.3.1 Parameters. Certain initial parameters are needed in order to follow the proposed methodology. These parameters are:

1. Type of traffic to mainly use the structure
2. Allowable rut depth
3. Subgrade condition
4. Condition of fill material

1. Type of Traffic

There are three vehicle types considered:

- Light vehicle (LV) - axle load < 2 tons
- Heavy vehicle (HV) - axle load < 12 tons
- Out of specification vehicle - unlimited axle load

If traffic is to consist of a mix of heavy and light vehicles (HV, LV), only the HV traffic is considered.

There are two levels:

$HV_1 - N < 10$ HV/Day

$HV_2 - 10 < N < 100$ HV/Day

where N = total traffic in both directions.

If traffic is to consist mainly of heavy vehicles and vehicles out of specification, the total weight (TW) the structure will be subjected to during its service life must be considered.

$HV_a - TW < 9070$ tons

$HV_b - TW > 9070$ tons

$OS - TW > 100{,}000$ tons

2. Rut Depth

The allowable rut depths for the different structures depend on the surface condition desired. The range of allowable rut depths is from 1 to 3 in.

3. Subgrade Condition

Subgrades with CBR less than 2 are considered in these applications. In the event that a subgrade is encountered with $2 < CBR < 3$ and a geotextile is proposed, it is suggested that the geotextile property specifications be reduced by one class to take into account the increased subgrade strength.

4. Fill Material

Three types of fill material are distinguished.

- G1
  - crushed materials with $20 < D < 80$ mm, where 0% of material is greater than D
  - well graded grain size distribution
  - $C_c = \dfrac{(D_{30})^2}{D_{60} * D_{10}} > 1$
  - Percentage of particles smaller than 80 μ < 10%
- G2
  - clean gravel, with $20 < D < 250$ mm and $D <$ one-half the height of fill
  - well graded grain size distribution
- G3
  - natural sand-gravel mixture, with $20 < D < 250$ mm and $D <$ one-half the height of fill
  - more or less well graded grain size distribution

Poorly graded materials as fill material are not addressed in this system.

4.1.3.2 Procedure. The following procedure will yield the depth of fill required and the geotextile specifications.

1. Determine the initial parameters of the structure to be designed.
2. Knowing the undrained shear strength of the subgrade, determine the necessary depth of fill in conjunction with a geotextile using the U.S.

Forest Service method (Steward, et al., 1977).

3. With this depth and initial parameters (traffic, fill material, rut depth, and subgrade), refer to the chart corresponding to the parameters and obtain the geotextile property specifications.

4.1.4 Establishment of Grab, Burst, and Puncture Strength Classes

The French system did not provide property specifications for grab strength, puncture strength, or burst strength. However, for separation applications these properties are important indices for fabric survivability and need to be specified.

Subgrade conditions prior to fabric placement, the type of construction equipment. and any special techniques in construction must be considered. Tables such as those found in the FHWA Geotextile Design & Construction Guidelines (Christopher and Holtz, 1988) have been developed for fabric survivability as a function of the above mentioned factors.

In order to develop specifications for grab, puncture, and burst strength for the cases which are considered in this research, the FHWA Geotextile Design & Construction Guidelines (Chrisopher and Holtz, 1988) was used. Table 4-1 supplies the required degree of fabric survivability as a function of cover material and construction equipment. The various subgrade conditions and preparations were not considered, as it was assumed the site will be cleared of all obstacles and the surface will be reasonably smooth and level. The different cases were matched with the conditions in the Table to come up with geotextile specifications depending on the fill material. In order to establish these specifications, assumptions were made with regard to the initial lift thickness

Table 4-1
Relationship of Construction Elements to Severity of Loading Imposed on a Geotextile in Roadway Construction (Christopher and Holtz, 1988)

		SEVERITY	
VARIABLE	LOW	MODERATE	HIGH TO VERY HIGH
Equipment	Lt. wt. dozer (8 psi)	Med. wt. dozer; lt. wheeled equip. (8-40 psi)	Heavy wt. dozer; loaded dump truck (>40 psi)
Subgrade Condition	Cleared	Partially cleared	Not cleared
Subgrade Strength (CBR)	<0.5	1-2	>3
Aggregate	Rounded sandy gravel	Coarse angular gravel	Cobbles, blasted rock
Lift Thickness (in.)	18	12	6

and the construction equipment. An initial lift thickness of 6 to 12 in. and heavy ground pressure equipment were assumed in the construction procedure. From this table the degrees of survivability required were obtained and then minimum fabric properties taken from Table 4-2.

Note: For thicker initial lift thicknesses or lower
ground pressure equipment, reduce grab,
puncture, and burst strengths one class.

The charts which resulted from incorporating the French grids with the survivability requirements are shown in Figures 4-5 and 4-6.

4.1.5 Example

The following example is taken from the *FHWA Geotextile Engineering Manual* (Chrisopher and Holtz, 1985), pg 4-117, to illustrate the use of combining the Forest Service Method with the French system to establish geotextile property specifications.

GIVEN:

1. A low-strength cohesive subgrade, $c_u = 4$ psi (CBR approx.= 1).
2. Expected loading from 5,000 passes of a 20,000-lb single axle load (10,000-lb single wheel loading) with tire inflation pressure of 80 psi.

REQUIRED: Design an effective roadway system.

Table 4-2
Survivability Requirements for Geotextiles in Roadway Construction
(Christopher and Holtz, 1988)

AASHTO-AGC-ARTBA JOINT COMMITTEE
(INTERIM SPECIFICATIONS)
MINIMUM[1] FABRIC PROPERTIES REQUIRED FOR FABRIC SURVIVABILITY

Required Degree of Fabric Survivability	Grab Strength[2] (minimum values) (lb)	Puncture Strength[3] (lb)	Burst Strength[4] (psi)	Trap[5] Tear (lb)
Very High	270	110	430	75
High	180	75	290	50
Moderate	130	40	210	40
Low	90	30	145	30

[1] All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the minimum values in this table). Note: These values are normally 20% lower than manufacturer's reported typical values

[2] ASTM D-4632, Grab Method.

[3] ASTM D-Proposed. Tension Testing Machine with ring clamp, steel ball replaced with a 5/16 inch diameter solid steel cylinder with flat tip centered within the ring clamp.

[4] ASTM D-3787, Diaphragm Test Method.

[5] ASTM D-4535, either principal direction.

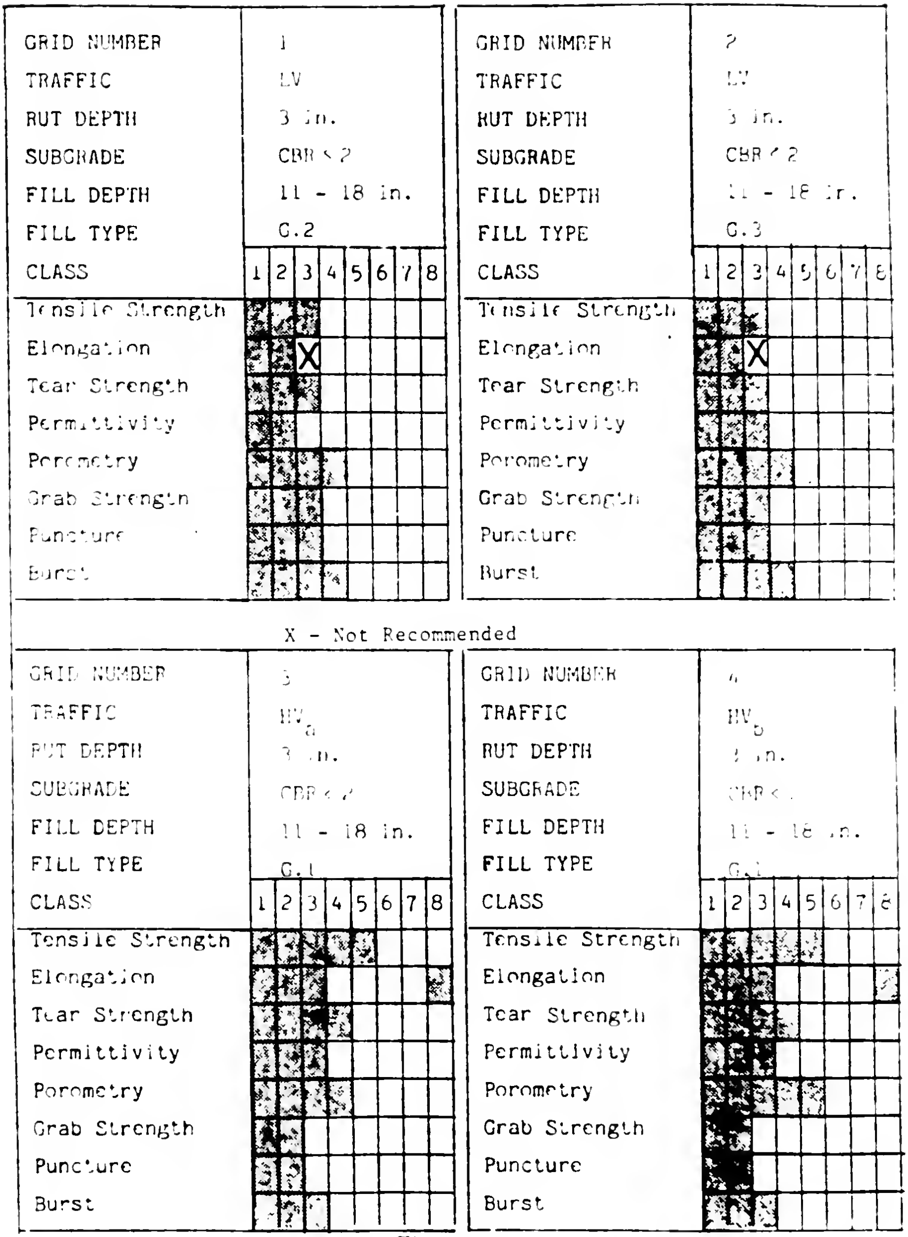

Figure 4-5
Geotextile Specification Charts

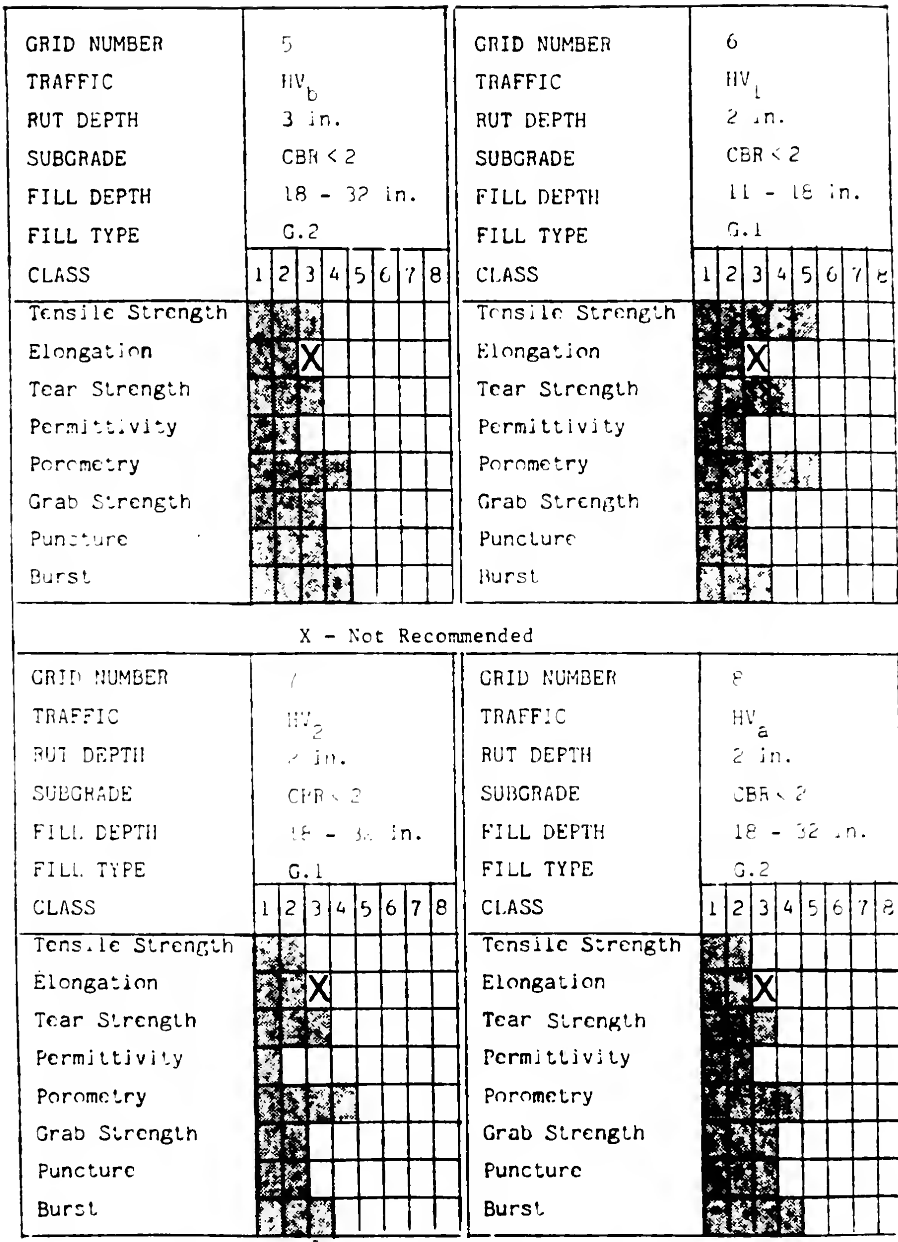

Figure 4-6
Geotextile Specification Charts

SOLUTION:

Determine aggregate depth from Forest Service charts.

$N_c = 5.0$ for more than 1000 passes and using a fabric.

$cN_c = 20$ psi

From Fig. 4-1--minimum aggregate = 14 inches.

1. Type of Traffic

Axle Load = 10 tons < 12 tons

Therefore, HV traffic

Total Weight = 5,000 * 10 tons = 50,000 tons

Therefore, HV_b traffic.

2. Referring to charts

Knowing: Aggregate depth = 14 inches, HV_b traffic

Therefore, Grid No. 4 matches most closely.

Note: Grid No. 4 has G.1 fill material; for different fill material property specifications may be changed accordingly.

3. Establish property classes

PROPERTY	*CLASS*	*PROPERTY VALUE*
Tensile Strength	5	> 100 psi
Elongation(ϵ)	$3 < \epsilon < 8$	$25\% < \epsilon < 100\%$
Trapezoidal Tear	4	> 200 lb
Permittivity	3	$> 0.1\ s^{-1}$
AOS	5	$> 150\ \mu m$
Grab Strength	2	> 130 lb
Puncture Strength	2	> 50 psi
Burst Strength	3	> 225 psi

4.2 Permanent Roads

In roadway design the primary geotextile function is that of separation. Placing a granular fill on top of a weak subgrade enables the load applied to the roadway surface to be distributed over a wider area of the subgrade. The subgrade is then more capable of supporting the load applied at the top surface. It is important to realize that the strength of the subgrade influences the roadway thickness, as the subgrade supports the roadway system (Christopher and Holtz, 1985). For weak subgrades without a geotextile, mixing between the granular base and subgrade causes a contamination of the base and a reduction in the strength of the granular material.

Rankilor (1981) states that the strength of a granular layer when supporting a surface load depends on the frictional contact between granular particles. The maximum frictional force is thereby achieved if (1) the particles are dry, (2) the particles are clean, (3) the particles are in firm contact with one another, (4) the

particles are angular in shape, and (5) the particle size distribution is well graded. Contamination of the granular material by a soft subgrade would affect the first three of the above criteria, and hence reduce the strength of the material. Figure 4-7 shows schematically how this strength reduction occurs.

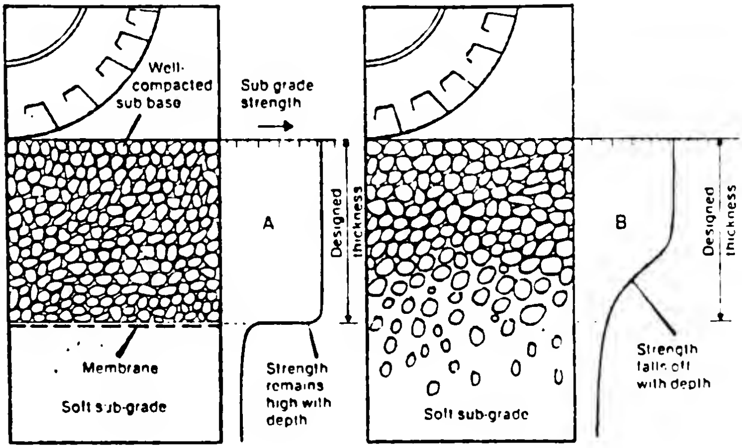

Figure 4-7
Road Strength Variation With and Without a Geotextile
(John, 1987)

Permanent roads are characterized by being required to handle a large number of vehicle passes (i.e. over 1 million), and may be either paved or unpaved. Permanent roadways are designed as either flexible pavement, rigid pavement, or unpaved systems.

In permanent roadway design on weak subgrades (CBR values less than 3), it is common practice to provide additional aggregate to the base to stabilize the subgrade. No structural support is attributed to this stabilization aggregate. The purpose of this stabilization aggregate is to initially enable construction to take place. Another function of this stabilization aggregate is that it will become contaminated by the subgrade, while keeping the base and subbase free of contamination. However, there is no assurance that this will be the case.

Rather than using somewhat arbitrary methods of selecting the amount of stabilization aggregate, it is suggested that the stabilization aggregate be designed as a temporary roadway using the procedure outlined in the previous section. Benefits of this procedure include eliminating contamination of the base and subbase, knowing that the thickness of aggregate placed will remain constant and not contaminate the subgrade, and reducing the amount of aggregate used compared to other methods.

Above this aggregate the permanent structure is placed. The design of the roadway section is made as if the roadway is to be placed directly on the subgrade, meaning the stabilization aggregate is assumed to give no structural support.

4.2.1 Procedure:

1. Estimate the need for a geotextile based on the subgrade strength.
2. Design the roadway for structural support using normal pavement design methods.

3. Estimate the number of passes the construction equipment will make and the weight of the construction equipment.

4. Determine additional stabilization aggregate required during construction activities by designing this aggregate as a temporary road, as shown earlier.

5. Determine the geotextile specifications by going into the charts (Figures 4-5 and 4-6).

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary and Conclusions

A classification system was developed to be used as an aid in the writing of geotextile specifications. The system may be applied to applications such as routine filtration/drainage, erosion control, and roadway structures. Reinforcement is not addressed by the system.

The scales of classification from the French Committee of Geotextiles and Geomembranes was revised in order to make it more useful to the Indiana Department of Highways. The number of classes was reduced from 12 to 8 to simplify the system, and other important properties were added to adapt the system to routine IDOH applications. The properties included in the scales of classification and their significance to design were discussed.

Two design procedures for filtration/drainage, and erosion control applications were discussed. The FHWA procedure is recommended over the French system, since the FHWA procedure may be applied by having knowledge of necessary conditions needed to provide an adequate design: soil conditions, flow conditions, and fabric pore dimensions. A computer program has been developed that follows the FHWA procedure.

A procedure has been developed incorporating the U.S. Forest Service Method for the design of temporary roads and the French recommendations for the use of geotextiles in roads. The combined procedure provides the depth of aggregate required and the geotextile property specifications. The French Committee of Geotextiles and Geomembranes provided geotextile properties for 88 different cases. Many of these cases were determined to be unsuitable for IDOH applications due to excessive rut depth, multiple geotextile layers, or sufficient subgrade strength such that a geotextile was probably not necessary. The present system includes only eight cases needed for practical design. This procedure may also be used to determine the amount of stabilization aggregate for permanent roads.

5.2 Recommendations

The following are recommendations for the updating of this system:

1. Maintain a data base on how past projects using this system have performed. Geotextile projects designed both before the use of this system and with this system can supply valuable information.

2. As more testing of geotextiles takes place, a better understanding of how these index properties (tensile strength, elongation, etc.) relate to the performance in the field will be achieved. Alterations should be made to the system based on testing and field performance.

3. As the system is applied to other applications, properties other than those listed in the scale of classes can be considered (creep, temperature resistance, dynamic tearing, etc.).

4. A portion of this system has been computerized (the computer program for filtration/drainage, and erosion control). In the future the entire system should be computerized.

LIST OF REFERENCES

LIST OF REFERENCES

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APPENDIX

APPENDIX

A program has been developed for determining geotextile properties for filtration/drainage and erosion control applications. The purpose of this program is to assist in the writing of geotextile property specifications for these applications. The program follows the recommendations found in the *FHWA Geotextile Engineering Manual.*

A.1 Necessary Input to the Program

A. Geotextile Application

1. Filtration/Drainage
2. Erosion Control

B. Soil Type

1. $< 50\%$ passing U.S. #200 Sieve by weight
2. $> 50\%$ passing U.S. #200 Sieve by weight

C. Type of Flow

1. Steady State
2. Dynamic

D. Soil Grain Size Distribution

1. d_{10}
2. d_{15}

3. d_{60}

4. d_{85}

E. Soil Permeability (cm/sec)

F. Severity/Importance

1. Critical applications/severe conditions

2. Less critical applications/less severe conditions

A.2 Output Provided by the Program

A. Maximum/minimum geotextile AOS

B. Fabric permeability (cm/sec)

C. Grab strength (lb)

D. Elongation (%)

E. Puncture strength (lb)

F. Burst strength (psi)

G. Trapezoidal tear (lb)

A.3 Running the Program

The program has been written in Fortran computer language. The program has the title "nsoil". The steps to run the program on an IBM or IBM compatible personal computer using Microsoft Fortran77 are:

1. Type "nsoil".

2. The screen will prompt you for the name of the output file. Enter this name after the prompt.

3. Type in input parameters.

4. Once all of the input is placed in the computer, a summary of the input and the geotextile specifications is shown on the screen.

5. To check to make sure the input values are correct and to view the geotextile specifications more thoroughly, one may view the output file on the screen or get a printout.

An example problem is given, including the input and output, along with a copy of the program.

A.4 Example:

An underdrain is to be constructed adjacent to a highway in order to lower and maintain the existing water table below the adjacent pavement structure. The grain size distribution curve is given on the following page for soils found along the highway alignment. Select the best enginering fabric to line the underdrain for the given soil conditions.

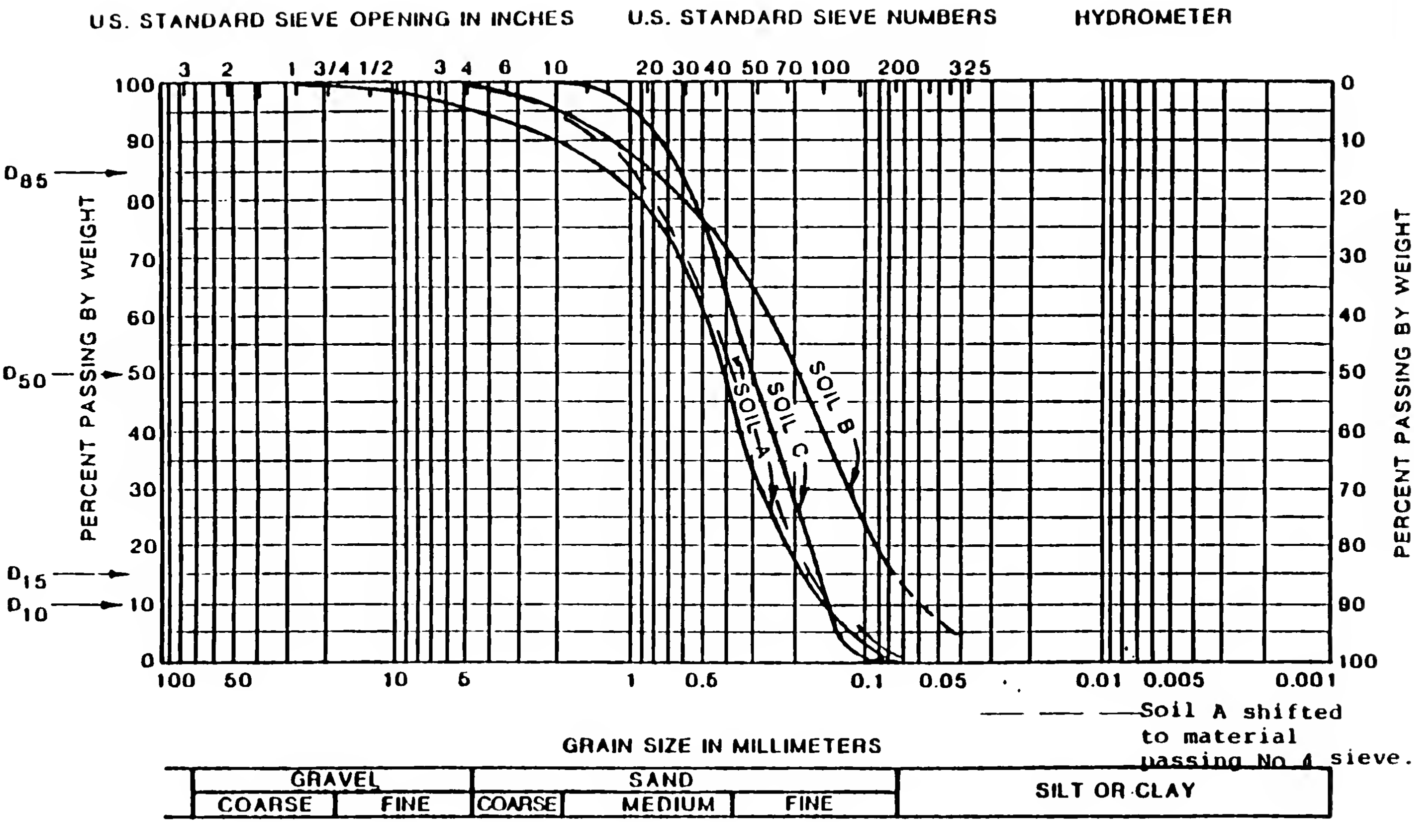
The geotextile will be used in a filtration/drainage application. From Carroll's guidelines the geotextile is to be used in a non-critical application/non-severe condition.

The permeabilities for the soils have been found to be:

Soil A - 0.05 cm/s

Soil B - 0.01 cm/s

Soil C - 0.04 cm/s



Grain size distribution of Natural Soils in Underdrain Example Problem

INPUT DATA

Filtration/Drainage Application
Flow -- Steady State
Soil -- < 50% passing #200 sieve
Less Critical/Less Severe Application

Soil Gradation #1
d(10) in mms = .150
d(15) in mms = .180
d(60) in mms = .500
d(85) in mms = 1.000

Soil permeability = .500E-01 cm/s.

Soil Gradation #2
d(10) in mms = .060
d(15) in mms = .075
d(60) in mms = .250
d(85) in mms = .750

Soil permeability = .100E-01 cm/s.

Soil Gradation #3
d(10) in mms = .150
d(15) in mms = .160
d(60) in mms = .380
d(85) in mms = .600

Soil permeability = .400E-01 cm/s.

GEOTEXTILE SPECIFICATIONS:

Maximum AOS(mm) = .760

If clogging is of concern, then
according to the clogging qualifiers:
Minimum AOS(mm) = .225
Minimum o15(mm) = .225

Fabric permeability = .500E-01 cm/s

Property	Class A Fabrics	Class B Fabrics
Grab Strength(lbs)	180.000	80.000
Elongation(%)	.000	.000
Puncture Strength(lbs)	80.000	25.000
Burst Strength(psi)	290.000	130.000
Trapezoidal Tear(lbs)	50.000	25.000

Elongation for filtration/drainage applications
is not specified by Task Force 25.

From Table 2-1 the following geotextile classes are determined:

Class A Fabrics

Property	*Class*
AOS	< 4
Grab Strength	> 3
Elongation	-
Puncture Strength	> 3
Burst Strength	> 4
Trapezoidal Tear Strength	> 2

Class B Fabrics

Property	*Class*
AOS	< 4
Grab Strength	> 1
Elongation	-
Puncture Strength	> 1
Burst Strength	> 2
Trapezoidal Tear Strength	> 1

```
c   Desion of Geotextiles for Common Filtration/Drainaoe
c      and Erosion Control Aoolications.
c
       real d10(10).d15(10).d60(10).d85(10).cu.b.kfab(10).maxperm
       real minaos.mino50.minwov.minnw.o95(10).o15(10)
       real o50(10).AOS(10).perm(10)
       real wovaos(10). nonwov(10).mino95. mino15
       inteoer napp. soil. flow. imove
       character*10 fname
       write(*.10)
  10   format(//.1x.t20.'Geotextile Specification Prooram for'./.
     ?  t14.' Filtration. Drainaoe/Erosion Control Aoolications'.///)
       write(*.20)
  20   format(1x.'Name of outout file to be created: '.ö)
       read(*.'(a)')fname
       open(unit=6.file=fname.status='new')
       write(*.30)
  30   format(//.1x.'GEOTEXTILE APPLICATIONS:'./.
     ? 5X.'1.  Filtration and Drainaoe'./.
     ? 5X.'2.  Erosion Control'./.
     ? 1X.'Please choose the number(1 or 2) 'ö)
       read(*.*)napp
  40   if(napp.ne.1.and.napp.ne.2)then
            write(*.*)'Please type "1" or "2"'
            read(*.*)napp
            ooto 40
       endif
       write(*.70)
  70   format(/.1X.'TYPE OF FLOW'./.5X.
     ?          '  1. Steadv State'./.5X.
     ?          '  2. Dynamic'./.
     ? 1X.'Please choose the number(1 or 2) of the flow. 'ö)
       read(*.*)flow
 100   if(flow.ne.1.and.flow.ne.2)then
            write(*.*)'Please tvpe 1 or 2'
            read(*.*)flow
            ooto 100
       endif
       if(flow.eo.2)then
            write(*.110)
 110        format(/.1x.'Can the soil move beneath the fabric?'.
     ?        /.5x.'1. Yes'./.5x.'2. No'./.1x.'Choose 1 or 2 '.ö)
            read(*.*)imove
 120        if(imove.ne.1.and.imove.ne.2)then
                 write(*.130)
 130             format(1x.'Please tvpe 1 or 2 '.ö)
                 read(*.*)imove
                 ooto 120
            endif
       endif
       write(*.190)
 190   format(/.1X.'SEVERITY/IMPORTANCE'./.
     ?        5X.'1. Critical/severe applications'./.
```

```
     ?       5X. 2. Less critical/ less severe applications'./.
     ? 1X.'Choose the number(1 or 2) of the severity/importance.'ö)
      read(*.*)import
 200  if(import.ne.1.and.import.ne.2)then
          write(*.*)'Please type 1 or 2'
          read(*.*)import
          goto 200
      endif
      write(*.50)
  50  format(/.1X.'SOIL TYPE:'./.5X.
     ? '1.  < 50% passing U.S. #200 sieve by weight'./.5X.
     ? '2.  > 50% passing U.S. #200 sieve by weight'./.
     ? 1X.'Please choose the number(1 or 2) of soil type 'ö)
      read(*.*)soil
  60  if(soil.ne.1.and.soil.ne.2)then
          write(*.*)'Please type 1 or 2'
          read(*.*)soil
          goto 60
      endif
c
c Prompt user for number of soil gradations
c   to analyze.
c
      write(*. 135)
 135  format(/.1X.'Number of soil gradations to analyze? './.
     ?       6X.'(maximum of 10): 'ö)
      read(*.*)ntype
 136  if(ntype.lt.1.and.ntype.gt.10)then
          write(*.*)'Number must be between 1 and 10'
          read(*.*)ntype
          goto 136
      endif
      do 555 k = 1. ntype
      write(*.140)k
 140  format(/.1X.'SOIL DESCRIPTION FOR GRADATION # '.i1./.
     ?       1X.'Please enter the following values:'./.
     ?       6X.'d(10) in mms = 'ö)
      read(*.*)d10(k)
      write(*.150)
 150  format(6X.'d(15) in mms = 'ö)
      read(*.*)d15(k)
      write(*.160)
 160  format(6X.'d(60) in mms = 'ö)
      read(*.*)d60(k)
      write(*.170)
 170  format(6X.'d(85) in mms = 'ö)
      read(*.*)d85(k)
      write(*.180)
 180  format(/.1X.'Soil permeability (cm/sec) = 'ö)
      read(*.*)perm(k)
c
c  Retention criteria
c
      if(soil.eq.1)then
```

```
          if(flow.eq.1)then
               cu = d60(k)/d10(k)
               b = 1.0
               if(cu.ge.2.0.and.cu.le.4.0)b = 0.5*cu
               if(cu.gt.4.0.and.cu.lt.8.0)b = 8.0/cu
               AOS(k) =  b * d85(k)
          else
               if(imove.eq.1)then
                  AOS(k) = d15(k)
               else
                  o50(k) = 0.5 * d85(k)
               endif
          endif
      else
          if(flow.eq.1)then
               wovaos(k) = d85(k)
               nonwov(k) = 1.8 * d85(k)
               if(wovaos(k).lt.0.3)wovaos(k) = 0.3
               if(nonwov(k).lt.0.3)nonwov(k) = 0.3
          else
               o50(k) = 0.5 * d85(k)
          endif
      endif
c
c Permeability requirement
c
      if(import.eq.1)then
          kfab(k) = 10.0 * perm(k)
      else
          kfab(k) = perm(k)
      endif
c
c  Clogging criteria qualifiers
c
c  The first equation requires the openings in the fabric
c   to be large enough to allow all the fines to pass.
c
          o95(k) = 3.0 * d15(k)
c
c  If one wanted to ensure that most of the smaller pores
c    were large enough to allow the fines to pass, a
c    minimum pore size could be specified as:
c
          o15(k) = 3.0 * d15(k)
  555 continue
c
c  Determine retention values and clogging values
c
      minnw = nonwov(1)
      minwov = wovaos(1)
      minaos = AOS(1)
      mino50 = o50(1)
      mino95 = o95(1)
      mino15 = o15(1)
```

```
      maxoerm = 0.0
      do 777 kk = 1. ntvoe
         if(AOS(kk).lt.minaos)minaos = AOS(kk)
         if(wovaos(kk).lt.minwov)minwov = wovaos(kk)
         if(nonwov(kk).lt.minnw)minnw = nonwov(kk)
         if(o50(kk).lt.mino50)mino50 = o50(kk)
         if(kfab(kk).ot.maxoerm)maxoerm = kfab(kk)
         if(o95(kk).lt.mino95)mino95 = o95(kk)
         if(o15(kk).lt.mino15)mino15 = o15(kk)
 777  continue
c
c  Constructabilitv and Survivabilitv Reouirement
c      (From Task Force Recommendations)
c
c      Filtration and drainage applications
c        For these applications. elongation is not specified.
c
      if(naoo.eo.1)then
          osa = 180.0
          osb = 80.0
          osa = 80.
          osb = 25.
          bsa = 290.
          bsb = 130.
          tta = 50.
          ttb = 25.
          ela = 0.
          elb = 0.
c
c      Erosion control applications
c
      else
          osa = 200.
          osb = 90.
          ela = 15.
          elb = 15.
          osa = 80.
          osb = 40.
          bsa = 320.
          bsb = 145.
          tta = 50.
          ttb = 30.
      endif
c
c  Echo of inout data
c
      write(*.210)
      write(6.210)
  210 format(//1x.'INPUT DATA'./)
      if(naoo.eo.1)then
         write(*.215)
         write(6.215)
  215    format(1x.t5.'Filtration/Drainage Application')
      else
```

```
         write(*,216)
         write(6,216)
 216     format(1x,t5,'Erosion Control Application')
      endif
      if(flow.eq.1)then
         write(*,220)
         write(6,220)
 220     format(1x,t5,'Flow -- Steady State')
      else
         write(*,230)
         write(6,230)
 230     format(1x,t5,'Flow -- Dynamic')
      endif
      if(soil.eq.1)then
         write(*,240)
         write(6,240)
 240     format(1x,t5,'Soil -- < 50% passing #200 sieve')
      else
         write(*,250)
         write(6,250)
 250     format(1x,t5,'Soil -- > 50% passing #200 sieve')
      endif
      if(import.eq.1)then
         write(*,280)
         write(6,280)
 280     format(1x,t5,'Critical/Severe Application')
      else
         write(6,290)
         write(*,290)
 290     format(1x,t5,'Less Critical/Less Severe Application')
      endif
c
      do 255 l1 = 1,ntype
         write(*,256)l1
         write(6,256)l1
 256     format(/,1X,'Soil Gradation #',i1)
         write(*,260)d10(l1),d15(l1),d60(l1),d85(l1)
         write(6,260)d10(l1),d15(l1),d60(l1),d85(l1)
 260     format(1x,t7,'d(10) in mms = ',f6.3,/,
     ?          t7,'d(15) in mms = ',f6.3,/,
     ?          t7,'d(60) in mms = ',f6.3,/,
     ?          t7,'d(85) in mms = ',f6.3,/)
         write(*,270)perm(l1)
         write(6,270)perm(l1)
 270     format(1x,t5,'Soil permeability = ',e10.3,' cm/s.')
 255  continue
c
c  Output results
c
      write(*,300)
      write(6,300)
 300  format(/1x,'GEOTEXTILE SPECIFICATIONS:',/)
c
 305   if(soil.eq.1)then
```

```
          if(flow.eq.1)then
               write(*,320)minaos
               write(6,320)minaos
 320           format(1X,t5,'Maximum AOS(mm) = ',f6.3,/)
          else
               if(imove.eq.1)then
                  write(*,330)minaos
                  write(6,330)minaos
 330              format(1x,t5,'Maximum AOS(mm) = ',f6.3,/)
               else
                  write(*,340)mino50
                  write(6,340)mino50
 340              format(1X,t5,'Maximum o50(mm) = ',f6.3,/)
               endif
          endif
      else
          if(flow.eq.1)then
             write(*,350)minwov,minnw
             write(6,350)minwov,minnw
 350         format(1X,t5,'For a woven geotextile, AOS(mm) = ',f6.3,/
     ¬       1X,t5,'For a nonwoven geotextile, AOS(mm) = ',f6.3,/)
          else
             write(*,360)mino50
             write(6,360)mino50
 360         format(1X,t5,'o50 = ',f6.3,/)
          endif
      endif
      write(*,365)mino95,mino15
      write(6,365)mino95,mino15
 365  format(1X,t5,'If clogging is of concern, then',/,
     ¬        t8,'according to the clogging qualifiers:',/,
     ¬        t10,'Minimum AOS(mm) = ',f6.3,/,
     ¬        t10,'Minimum o15(mm) = ',f6.3,/)
      if(import.eq.1)then
          write(*,370)
          write(6,370)
 370      format(5x,'Note: For critical/severe applications',/,
     ¬      10x,' soil-fabric filtration tests should',/,
     ¬      10x,' be run(e.g. Gradient Ratio tests)',/)
      endif
c
      write(*,380)maxperm
      write(6,380)maxperm
 380  format(1X,t5,'Fabric permeability = ',e10.3,' cm/s',/)
      write(*,390)
      write(6,390)
 390  format(1X,t5,'Property',t30,'Class A Fabrics',t48,
     ¬        'Class B Fabrics',/)
      write(*,400)gsa,gsb,ela,elb,psa,psb,bsa,bsb,tta,ttb
      write(6,400)gsa,gsb,ela,elb,psa,psb,bsa,bsb,tta,ttb
 400  format(1X,t7,'Grab Strength(lbs)  ',t31,f8.3,t49,f8.3,/,
     ¬         6X,'Elongation(%)  ',t31,f8.3,t49,f8.3/,
     ¬         6X,'Puncture Strength(lbs)',t31,f8.3,t49,f8.3,/,
     ¬         6X,'Burst Strength(psi)',t31,f8.3,t49,f8.3,/,
```

```
     ?          6X.'Trapezoidal Tear(lbs)'t31.f8.3.t49.f8.3./)
      if(napp.eq.1)then
          write(*.410)
          write(6.410)
410       format(1x.'Elongation for filtration/drainage'.
     ?              ' applications'./.5X.' is not specified '.
     ?              'by Task Force 25.')
      endif
      stop
      end
```

PURDUE UNIVERSITY

SCHOOL OF CIVIL ENGINEERING

Implementation Report

There are a number of different geotextiles and related materials (geogrids, webs, nets, composites, etc.) currently on the market in the United States. These materials have a wide range of mechanical and hydraulic properties. A major problem in choosing a geotextile for highway design is the number and diversity of products available.

A classification system has been developed through this research to assist the Indiana Department of Highways in specifying geotextiles. This system may be used by the design engineer when considering the feasibility of using a geotextile in routine geotechnical applications. The routine geotechnical applications addressed by this system are:

1. Filtration drainage
2. Erosion control
3. Roadway structures

The system specifies those geotextile index properties necessary for an adequate design: wide-width tensile strength, maximum tensile elongation, trapezoidal tear strength, permittivity, apparent opening size, grab strength, puncture strength, and burst strength.

This system has been developed while giving appropriate consideration to IDOH traffic, construction, hydraulic, and soil conditions for the various applications.

CIVIL ENGINEERING BUILDING • WEST LAFAYETTE, IN 47907

COVER DESIGN BY ALDO GIORGINI